PERIODICA POLYTECHNICA SER. TRANSP. ENG. VOL. 28, NO. 1–2, PP. 123–130 (2000)

THE USE OF MODERN SATELLITE SYSTEMS IN THE RAILWAY TRAFFIC

Gábor Kálmán KISS

Department of Transport Operation
Budapest University of Technology and Economics
H–1152 Budapest, Hungary
Tel.: (36 1) 432 38 99 Fax: (36 1) 342 93 95

Received: October 12, 2000

Abstract

In this paper the satellite-based railway positioning systems are summarised. In the first part the advantages of the satellite-based railway systems, short summary of the GPS system and the application today are given. Further on a system model is presented which can help us to survey the whole transport process.

Keywords: satellite, positioning, passenger and freight transportation, GPS-based train influence system.

1. Introduction

The rail passenger and freight transportation has lost in market position not only in Hungary, but all over Europe. The passengers and carriers increasingly prefer the road transportation. The growing mobilisation in the passenger transport service, the need for quick travel and not least the price level are the factors that influence the passengers in choosing between different means of transport. There is only one way for the national railway companies to make up their loss of market and backlog. They should undertake significant technological innovations.

The satellite-based telecommunication and positioning systems are in practical use both in the USA and in Japan. The next pages will deal with the advantages of satellite-based railway systems and their development options.

2. The Advantages of the Satellite-Based Railway Systems

- The maintenance expenses of the rail-track can be reduced leaving out the outdoor equipment installed along the tracks (e.g. the breaking of electric circuits).
- The ‘compatibility errors’ can be eliminated by connecting local systems.
- Using satellite-based systems, the traffic safety can be enhanced on secondary lines without interlocking equipment.

- The damages caused by vandalism can be reduced leaving out the outdoor equipment.
- The bottlenecks are recognisable so it is possible to solve them in time.
- Integrated combined transport systems can be created by means of which the transparency of the traffic flow of material and means of transport would be increased.
- The introduction of 'Moving Block' (dynamic track sections) results in economic and environmental advantages. The traction parameters are improved (less traction energy consumption, reduced noise and dust pollution thanks to the better planned braking process).
- Large areas (even more countries) can be covered.
- Quick build up.
- Exact positioning and control of moving vehicles.

3. The GPS System

The NAVSTAR-GPS (**NAV**igation **S**ystem with **T**iming **A**nd **R**anging-**G**lobal **P**ositioning **S**ystem) has been developed for military use by the US Defence Ministry. The system – including 26 active satellites – ensures optimal covering in all corners of the Earth. The accuracy of the 'time and distance measuring' based system has increased to 4 meter since 1st January 2000 when Bill Clinton President of the US discontinued the SA (Selective Availability).

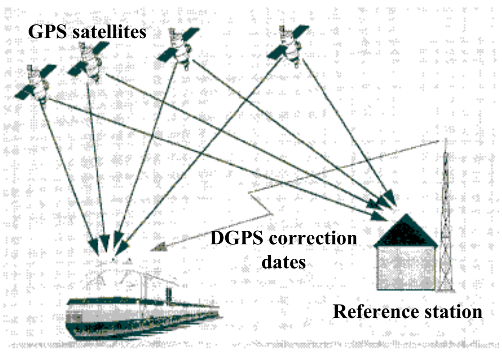

Fig. 1. DGPS system components

In the 90s there was in use a procedure that helped to reach the cm precision. It was called Differential GPS (DGPS). The fundamental idea was to transmit correction data from a reference station (*Fig. 1*), of which position was well known. The GPS receiver could work (depending on the duration and the speed) with correction data in the interval of 10–100 centimetres.

Level 5:

- Points with electric drive.
- Inductive signals (balises) can be used in case of intensive traffic.
- AULI: It sets the points and other track-objects in the right direction automatically.
- RZÜ: Course-diagram drawing method.
- Automatic train-influence equipment and speed-signalling display

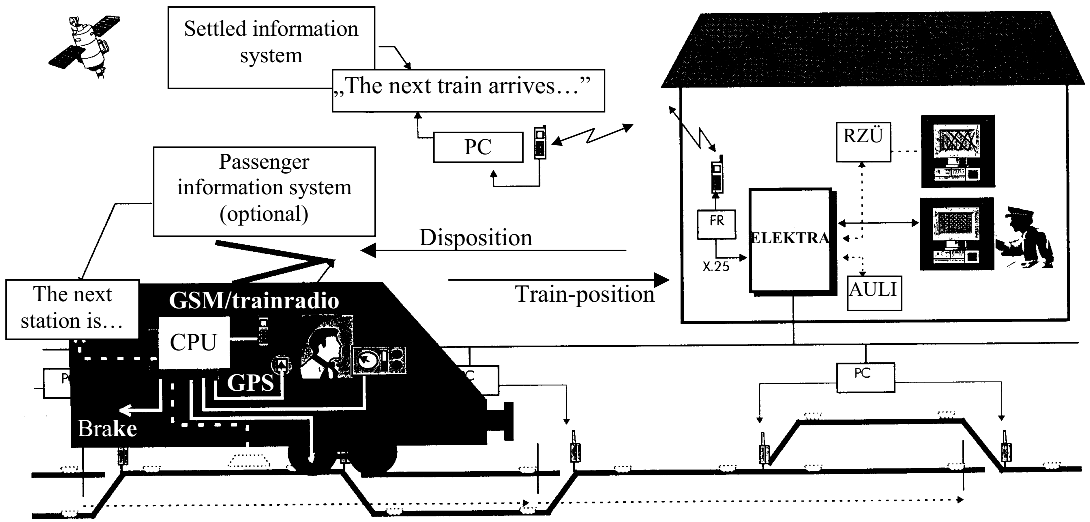

Fig. 2. ALCATEL's Secondary Lines Signalling System

4. Satellite-Based Railway Systems

The number of satellite-based railway systems is considerably behind the number of road transport systems. Their enumeration is easier and more obvious if we use the following 4-group collecting.

In the *first group* there are the GPS-based geodesy procedures. They are the first members of the satellite-based railway systems. They were firstly applied in territories where high accuracy was needed; however, the existence of security justification of the system was not among the requirements. Thanks to the GPS-based geodesy equipment the accuracy of route allocation can be improved and the survey of the existing routes can be done faster. This pioneer equipment is called SURVER [1] developed by the engineers of the DB AG. In 1994 this special field of geodesy got to the point that the measurements could be done with higher accuracy in a few hours. Earlier for the same work it was needed even more days.

In the *second group* there are the GPS-based train influence systems. They make possible to leave out the traditional track-electric-circuits. The following Austrian and Japanese applications are just a few examples in addition to the American systems (e.g. the Union Pacific Railway Companies Positive Train Separation [2]).

The Austrian ALCATEL Company has developed a new technology to control the transport on secondary lines carrying little traffic [3]. The GPS-based system guarantees a higher level of safety than the 'inter-station' system and its build up expense is also favourable.

The Secondary Lines Signalling System (SLSS) helps the work of traffic controllers because there is no need to give and ask for permission and the system also documents itself automatically.

To reduce the build up expenses engineers use spring points to allow crossing of trains. It is possible to save the operating and maintenance costs of cable laying equipment by the abandonment of the signals and track-electric-circuits. On industrial tracks ALCATEL uses key-locked points which can be opened and closed, if necessary, on the spot by the engine driver.

The SLSS is designed to work on 5 different levels (*Fig. 2*). The easiest function is the location of the train position and its display on the monitor installed in the Control Centre. The other utmost point is the GPS-based Train Command Centre. In this application the traffic controller is able to give dispositions to the trains or even the timetable-based computer can command the whole line. ALCATEL uses a train radio to exchange data between the control centre's computer and on-board equipment. The current speed or brake commands can bee seen on a monitor placed in the driver's cab so the traditional signals – along the track – can be left out.

The Japanese railway also has a GPS-based security system, called CARAT (Computer And Radio Aided Train Control System) [7].The main function of this system is to protect the maintenance group on the tracks. Each leader of these groups has a warning equipment. This mobile receiver gets the 'own position' data from the coming train. So the workers can leave the track safely before the train's arrival. The advantages of the system are the higher security and the lower expenses because the engine driver does not have to reduce the speed and increase it again. This safety equipment is on trial operation on the Joetshu-Shinkansen line.

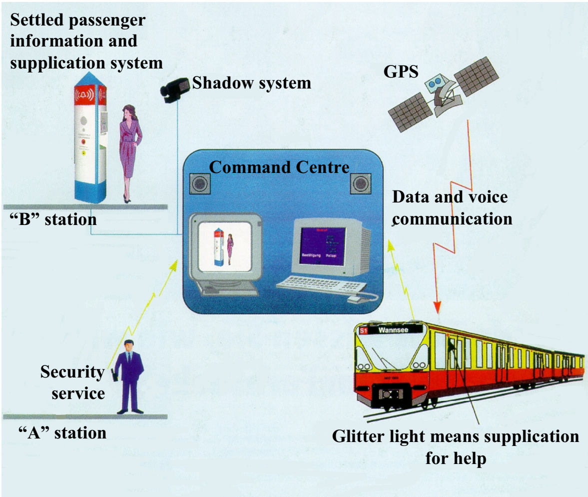

Fig. 3. S-Bahn Berlin-System overview

In the *third group* there are the railway transport systems. The most important and interesting application is the German mobile equipment, the **Sa**telliten-Ha**ndy** (Sandy) [4]. The basic idea was to prevent the damages of the goods that in Hungary reach up to 8%. These damages are caused not only by stealing and pilfering, but mostly by the shunting crew who are working with old technology and sometimes irregularly.

The SANDY can be mounted on the carriage (of course it is thief proof). Through its sensors the equipment is able to collect the parameters continuously and transfer them to the system operator via SMS (Short Massage System) or by train radio every 5–10 minutes. It is possible to adjust in advance the threshold values of the sensors. When the measured value is higher than the threshold value, SANDY will send an 'ALARM' message to the operator. After this message the necessary steps can be done.

Besides the satellite-based transport systems there is another application, the modern GPS-based passenger information systems constituting the *fourth group*. In Berlin (Germany) the S-Bahn supplements this information system (*Fig. 3*) with a communication system [5].

The passengers use it only in emergency situations. They either go to the settled passenger information and supplication box or ask for help on the board of the S-Bahn's train by pressing a button. The security service is regulated from the Command Centre to the GPS determined place.

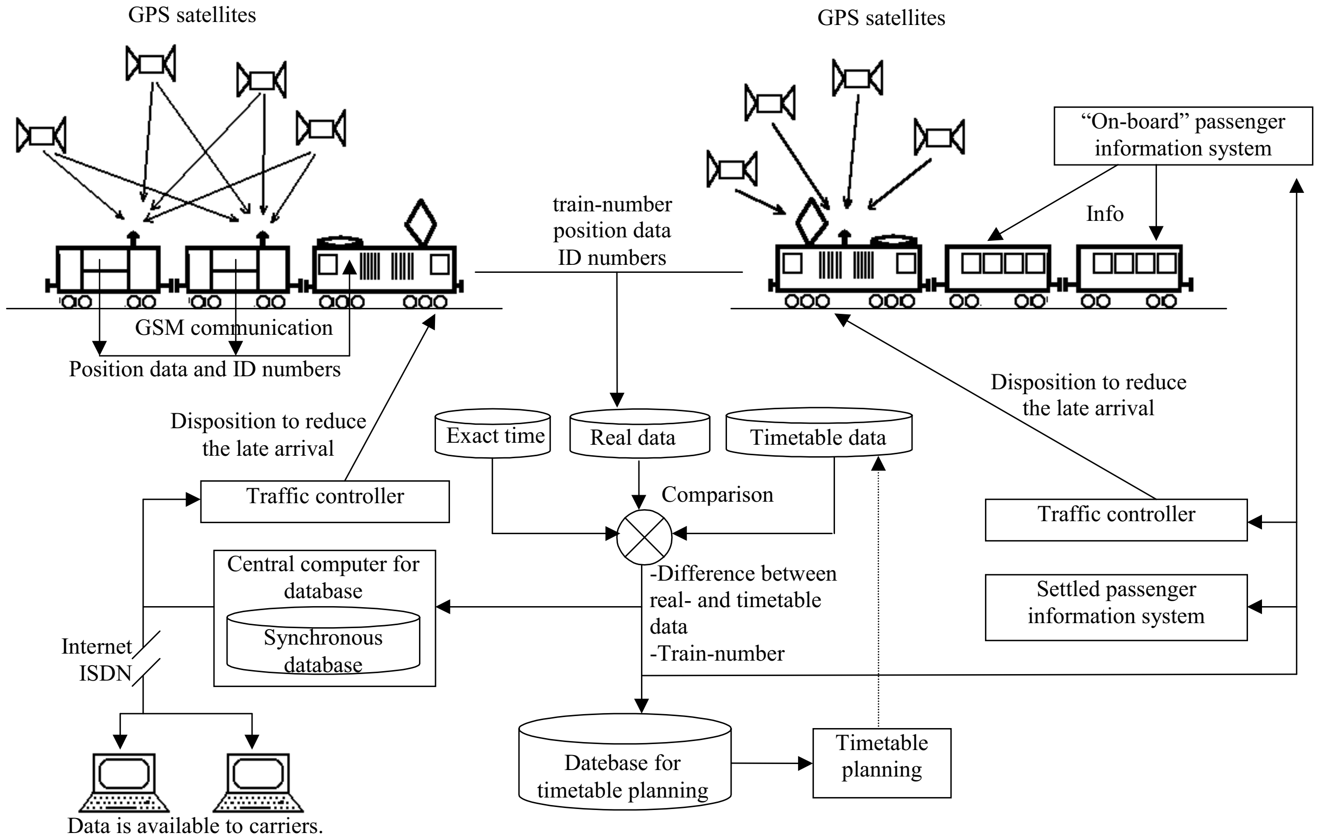

Fig. 4. Informatogram of the GPS-based passenger and freight transportation

The system works normally as an information system, naturally based on GPS positioning data.

5. Development Options

Today the rail passenger and freight transport systems are working isolated from each other. It is necessary to create a system model [6], which can help us to survey the whole transport process. This is the only way to see all the opportunities that satellite-based railway systems offer.

For *passenger transportation*, the satellite-based positioning offers the most in the field of passenger information.

The GPS-based *settled passenger information system* can automatically show the precise late arrival instead of the information nowadays '10 minutes late', or '15 minutes late'. This is the only way to increase the feeling of security, the calculableness and hereby the trust in the railway.

The *on-board information system* has a 3-step development option. In the first step a satellite-based Central Unit is connected to the waggons' tape recorders and loudspeakers. The name of the next station, the remaining time to the next stop and the possible late arrival can be automatically told to the passengers. The service level can be improved through the change of the information communication (e.g. using TV screen, or LCD monitor) or making it frequently. Possessing a database it is possible to inform the passengers about the name of the stations and sights along the track by using interactive monitors (*Fig. 4*).

Another important application of the satellite-based passenger systems is timetable planning. All information systems need the time differences between the timetable and the real data. By storage of these time differences we can create a database for timetable planning. This makes the work of the planning engineer easier and more precise.

The railway *freight transportation* has two different groups.

The first one is the '*one group train*', where all carriages have the same destination. The GPS followed object is only the engine, the carriages are followed just logically. Their positions can be established with a precision of 600–1000 meters (because of the greatest train length). Considering that the exact positioning data is not so important for the carriers it is allowed to follow just the train and not every carriage. The only weakness of the system is the human factor. For connecting the carriages logically to the GPS-based engine it is necessary to know their identification numbers. Before the departure the numbers have to be collected and transmitted (by radio) to the system. After that you can ask for the position of the carriages through the engine's position. When the train stops and when a carriage is uncoupled several times and later sent on with another train the risk of data missing is increasing. Besides the monitoring method should be strictly followed.

The second group of the rail freight transportation is the '*carriages following* *concept*'. It means that every waggon has its own GPS-based identification equipment, that can avoid data missing during the 'radio guided carriages data collecting'. The waggons with their ID numbers can be operated much easier.

The mobile equipment sends SMS messages to the engine, so it is cost-effective. The data from the engine will be transmitted to the traffic controller by using train radio contact. The time difference, i.e. the deviation from the timetable is representable on maps. Using the 'synchronous database' the traffic controller can be informed on the late arrival and so he is able to make a decision in time. On the basis of this information the rail freight transportation could be more automatic, precise and more accurate (e.g. statistics, valuations).

The data of transport are available for carriers. They can follow their freight in 'real time'. (The earlier systems followed the carriages just like cross-section. There was no possibility for continuous positioning registration. The carriers known only that the waggon was 'under transport', or it was 'being unloaded').

6. Summary

This paper offers a survey of the wide area of satellite-based railway positioning systems. The purpose was to outline an overall image and to systematize the applications. The keywords are the GPS-based geodesy procedure, the GPS-based train influence system and the satellite-based railway transport and information system. The different areas need different levels of safety information and positioning data, but all the applications are designed to put the railway forward, to stabilize its position on the transport market.

The satellite systems have a lot of advantages and their costs are immediately recovered. We hope that the satellite-based railway technologies have a great future.

References

[1] LUDWIG, S., GPS in the Railway Geodesy. (In German). *Eisenbahningenieur*, **9** (1997).
[2] SAUER, S. J., Burlington Northern Santa Fe GPS Survey Project. (In English). American Railway, 1997.
[3] HARTBERGER, M., Train Influence System by ALCATEL. (In German). Eisenbahnsicherungstechnik, 1999.
[4] The Little SANDY is Very Big in Collecting of Data. (In German). *Deine Bahn*, **8** (1999).
[5] JACOB – RENKEN, Passenger Security and Satellite-Based Positioning in S-Bahn Berlin. (In German). *SIGNAL+DRAHT*, **3** (1996).
[6] WESTSIK, GY., *Transportation Information Technology and Telematics*. (In Hungarian.) Műgyetemi Kiadó, 1997.
[7] GRÜLLER, R., NAVSTAR-GPS, the Global Positioning System. (In German.) *Eisenbahn-Revue*, **5** (1997), **6** 1997, **1–2** (1998).
[8] KLATT, K.: The Possibilities of the Use of GPS in the Passenger Information and Railway Line Control. (In German.) SIGNAL+DRAHT, **3** (1998).